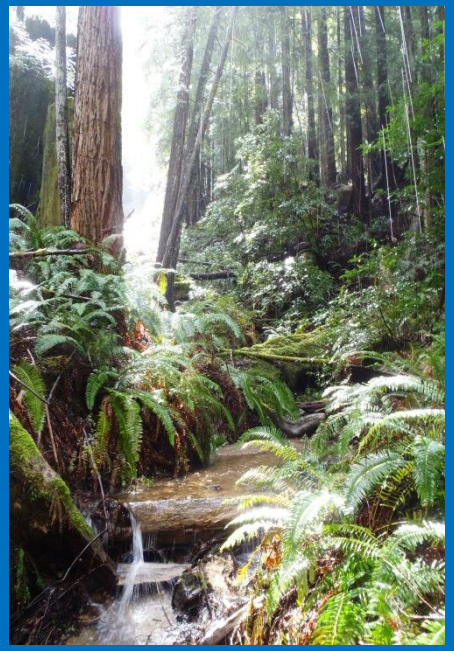
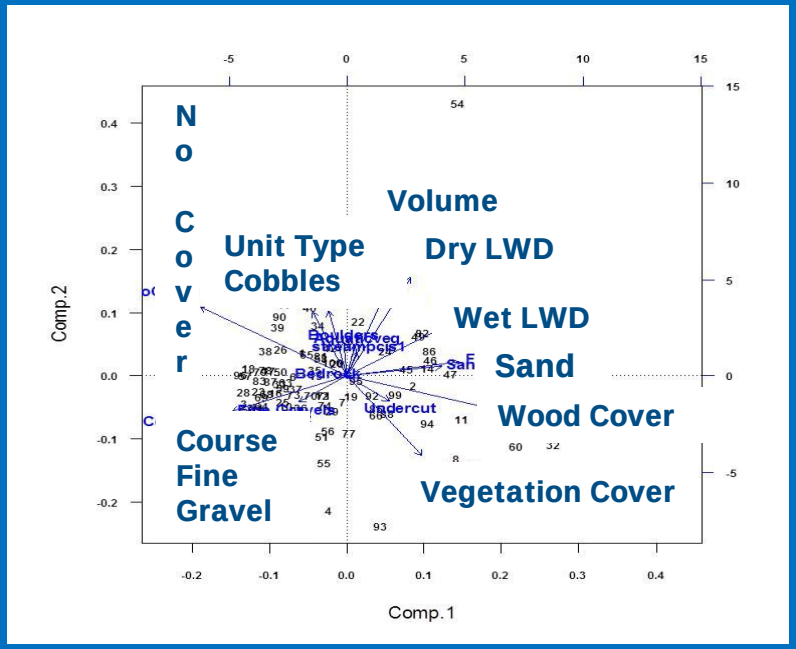
Linking Habitat Variables to Salmonid Growth, Survival, and Abundance in Two Coastal Northern California Intensively Monitored Watersheds





Sean P. Gallagher, Joe Ferreira, Emily Lang, Wendy Holloway, and David W. Wright

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

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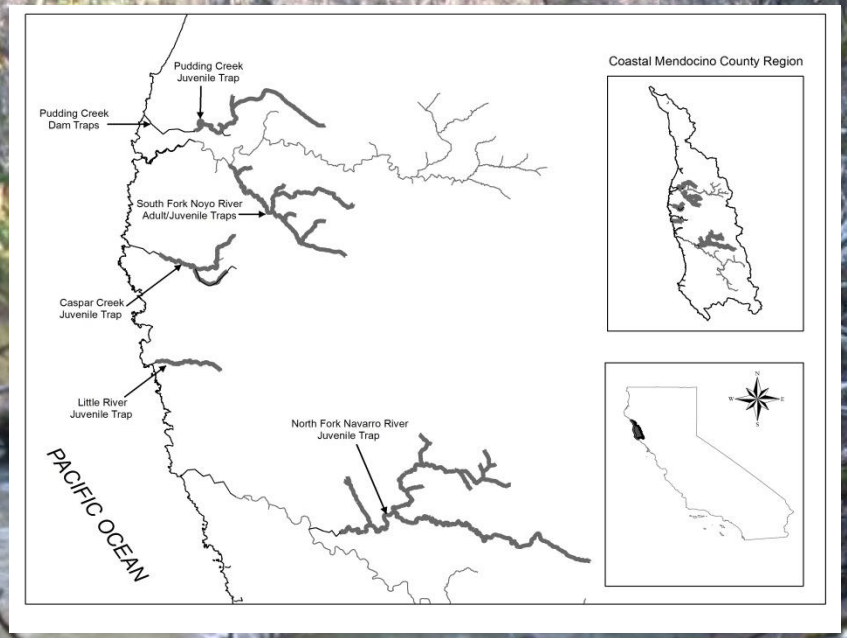
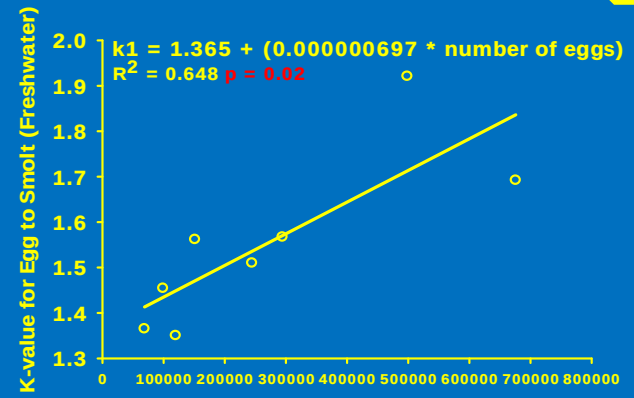
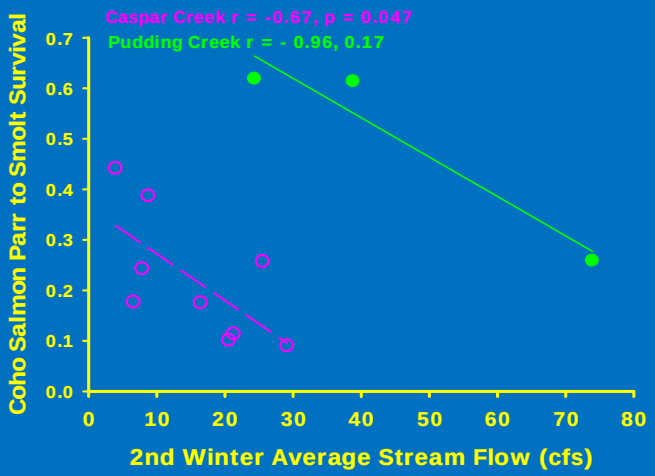
The Nature Conservancy

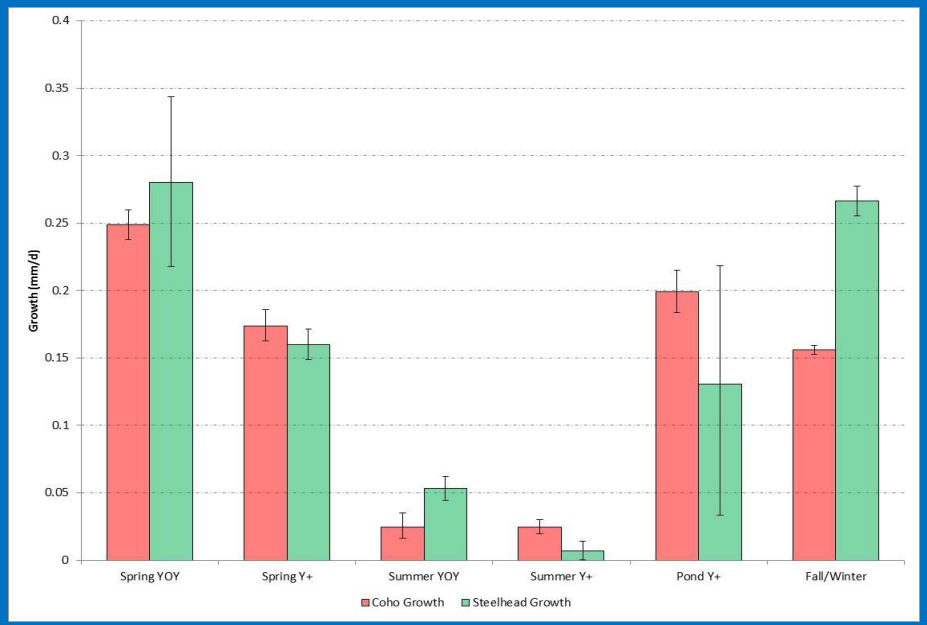

Pudding Creek
Juvenile Trap
Pudding Creek
Dam Traps
South Fork Noyo River
Adult/Juvenile Traps
Caspar Creek
Juvenile Trap
Little River
Juvenile Trap
North Fork Navarro River
Juvenile Trap
PACIFIC OCEAN
Coastal Mendocino County Region

Results 2000 to 2010

- ❑ Density Dependence
- ❑ Winter Habitat is Limiting
- ❑ Summer is Low Growth Period

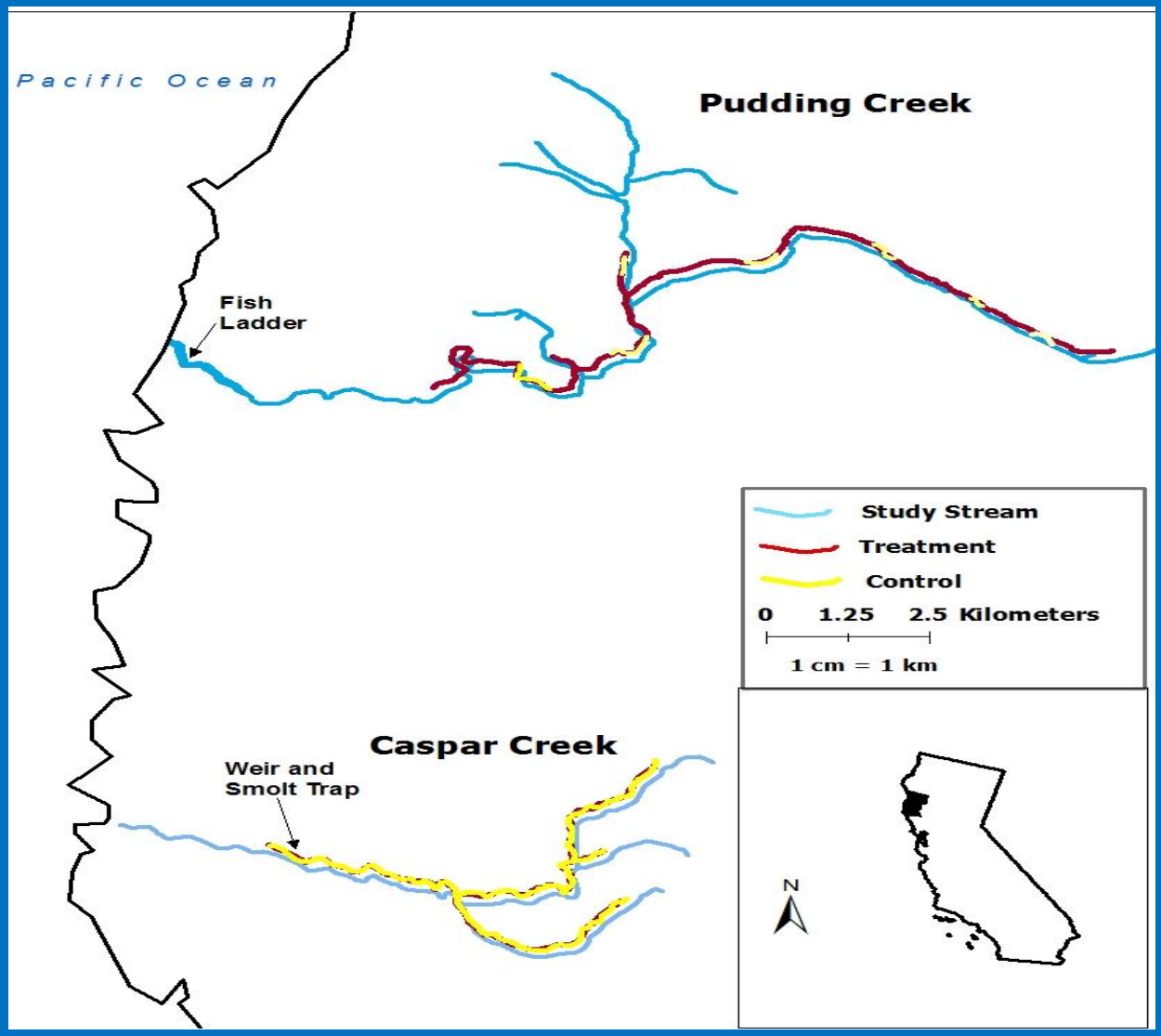






Will Addition of LWD Increase Habitat and Salmonid Abundance?

Before, After, Control, Impact Experiment



Analytical layout of population and habitat metrics for the BACI Experiment.

Parameter			Data collection period		
Physical Habitat			Pretreatment Years	Transition	Post Treatment
	Summer and winter	Habitat number, size, volume, heterogenaity, and geomentry	2013-2015	2015	2016-2019
		Channel Morphology/ geometry, substrare compostion, sinuosity	2013-2015	2015	2016-2019
		Wood density, volume, and rate of input	2013-2015	2015	2016-2019
		Seasonal stream flow, water temperature, and others (Bouwes et al. 2011)	2013-2015	2015	2016-2019
	Winter only	Percent slow water habitat, Percent off channel habitat, floodplan channel length	2012-2014	2015	2016-2019
Biological					
	Summer	Steelhead 0+ abundance	2006 -2010, 2012, 2013, 2014	2015	2016-2019
		Coho abundance	2006 -2010, 2012, 2013, 2014	2015	2016-2019
		Coho and Steelhead Growth*	2011-2014	2015	2016-2019
		coho and steelhead Survival	2011-2014	2015	2016-2019
	Winter	Coho and Steelhead Growth*	2011-2014	2015	2016-2019
		coho and steelhead Survival	2011-2014	2015	2016-2019
	Annual	Coho salmon and Steelhead smolt abundance	2006 -2010, 2012, 2013, 2014	2015	2016-2019
		Coho salmon and Steelhead adult abundance	2006 -2010, 2012, 2013, 2014	2015	2016-2019
		Over-summer survival	2006 -2010, 2012, 2013, 2014	2015	2016-2019
		Winter survival	2006 -2010, 2012, 2013, 2014	2015	2016-2019
		Habitat specific survival and growth	2011-2014	2015	2016-2019
		Proportion of two-year old coho residents	2006 -2010, 2012, 2013, 2014	2015	2016-2019

* This will also be related to speficic habitat unit types and site fidelity (Bell et al. 2003).

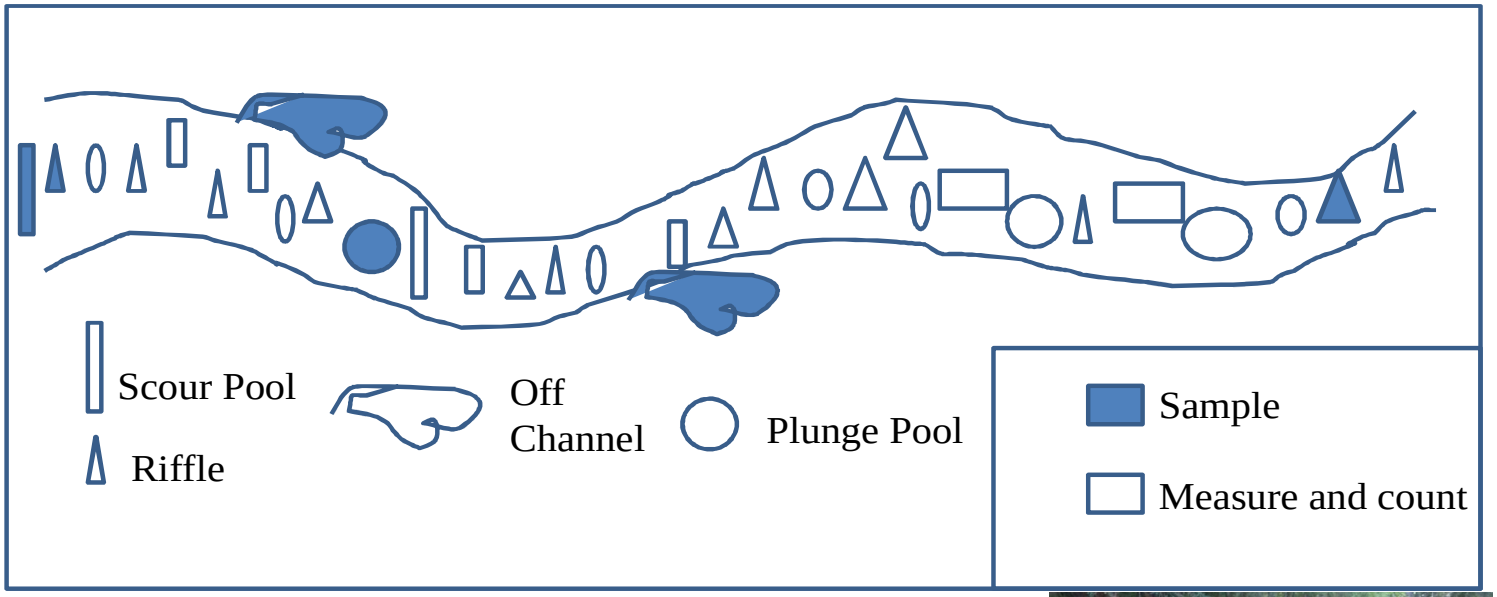
Detailed habitat variables collected in each selected unit in Caspar and Pudding creeks during summer 2013.

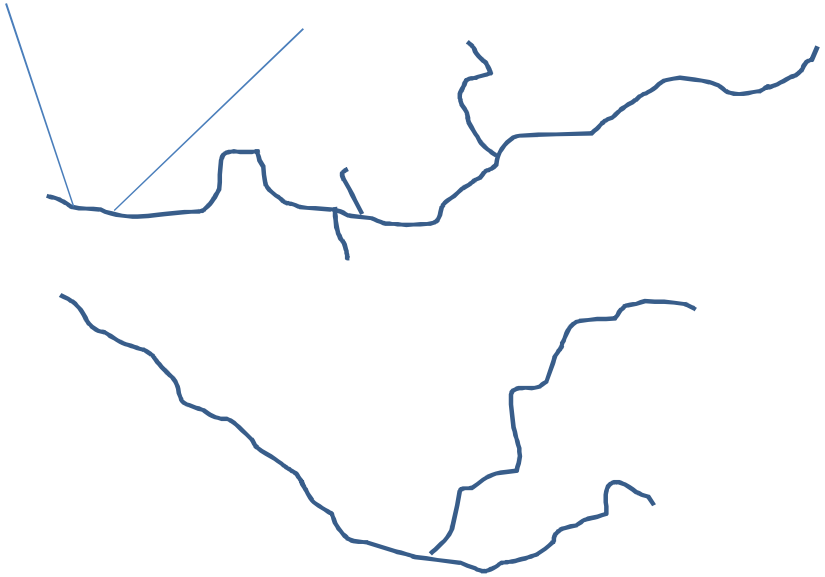
Habitat Unit Type	Percent Fish Cover	Substrate Composition	Measured Unit Variables	Calculated Unit Variables
Cascade*	Aquatic Vegetation	Bedrock	Average Depth	Residual Pool Depth[1]
Dam Pool*	Artificial Structures*	Boulders	Bankfull Width	Residual Pool Volume[1]
Dry Units*	Dead Woody Debris	Cobbles	Length	Unit Surface Area
Falls*	Live Overhanging Vegetation	Course Gravel	Maximum Depth[1]	Unit Volume
Non-Turbulent	No Cover	Fine Gravel	Pool Tail Crest Depth[1]	Dry LWD Abundance
Off Channel	Undercut Banks	Fines	Width	Wet LWD Abundance
Plunge Pool		Sand		Dry LWD Density
Rapid*		Pool Tail Fines < 2mm[1]		Wet LWD Density
Riffle		Pool Tail Fines 2-6mm[1]		
Scour Pool				

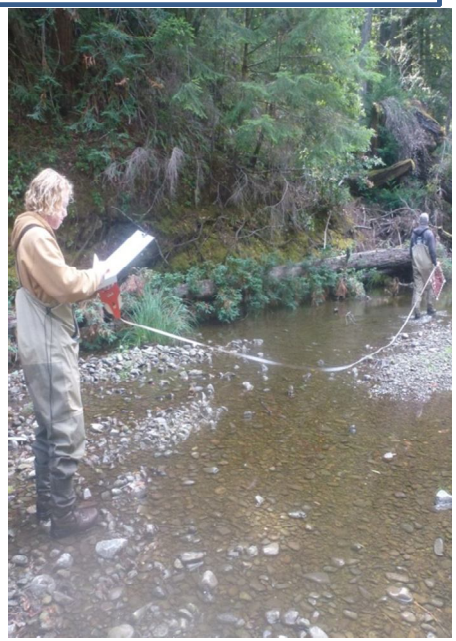
*Few or none encountered

[1] Pools only

Columbia Habitat Monitoring Program: Bouwes, N., J. Moberg, N. Weber, B. Bouwes, C. Beasley, S. Bennett, A. Hill, C. Jordan, R. Miller, P. Nelle, M. Polino, S. Rentmeester, B. Semmens, C. Volk, M. B. Ward, G. Wathen, and J. White. 2011. Scientific protocol for salmonid habitat surveys within the Columbia Habitat Monitoring Program. Prepared by the Integrated Status and Effectiveness Monitoring Program and published by Terraqua, Inc., Wauconda, WA


Scour Pool
Riffle
Off Channel
Plunge Pool
Sample
Measure and count





PACIFIC OCEAN

Pudding Creek

56
271
130
184
161
248
336

Caspar Creek

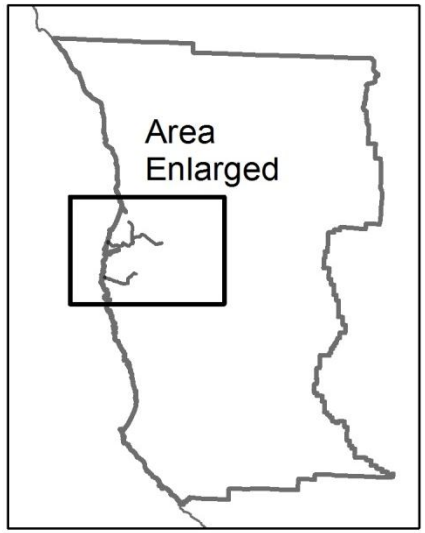
211
49
181
177
273

Habitat Unit Types

- Pool
- Riffle
- Non-Turbulent
- Off-Channel

0 1 2 4 6
Kilometers

Mendocino County



Salmonid Unit Abundance:

Coho Parr, Steelhead YoY, Y+, Y++

Habitat Unit Type	Percent Fish Cover	Substrate Composition	Measured Unit Variables	Calculated Unit Variables
Cascade*	Aquatic Vegetation	Bedrock	Average Depth	Residual Pool Depth[1]
Dam Pool*	Artificial Structures*	Boulders	Bankfull Width	Residual Pool Volume[1]
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Plunge Pool		Sand		Dry LWD Density
Rapid*		Pool Tail Fines < 2mm[1]		Wet LWD Density
Riffle		Pool Tail Fines 2-6mm[1]		
Scour Pool				

*Few or none encountered

[1] Pools only

“The relationship between any one habitat parameter and salmon and steelhead survival is difficult…. “

“It is easy to draw conclusions that the more pristine reference streams were better for salmon and steelhead, but more difficult to prove what specific mechanisms are at work.”

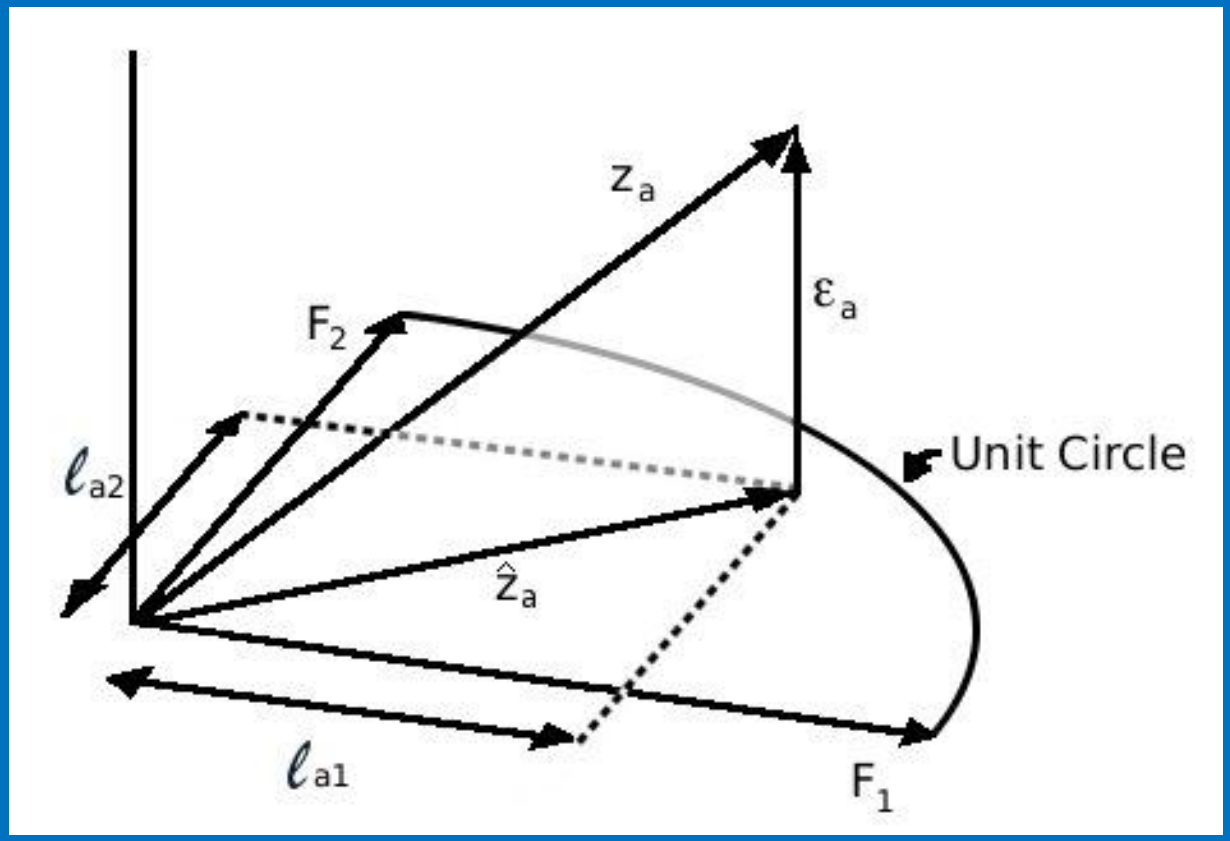
Crawford, B. A. and S. Rumsey. 2011. Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed Under the Endangered Species Act: Guidance to salmon recovery partners concerning prioritizing monitoring efforts to assess the viability of salmon and steelhead populations protected under the Federal Endangered Species Act. National Marine Fisheries Service, NW Region. 160 pp.

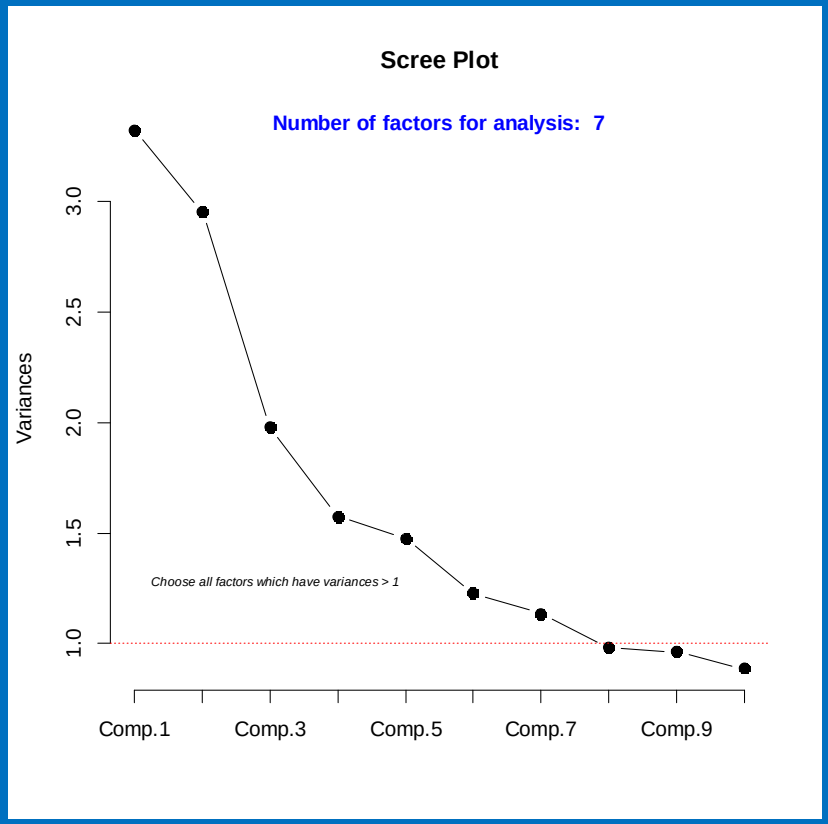

Unitlength
Averagewidth
Averagedepth
area
volume
Maxdepth
Wetlwdden
Drylwdden
wetlwdpeices
drylwdpieces

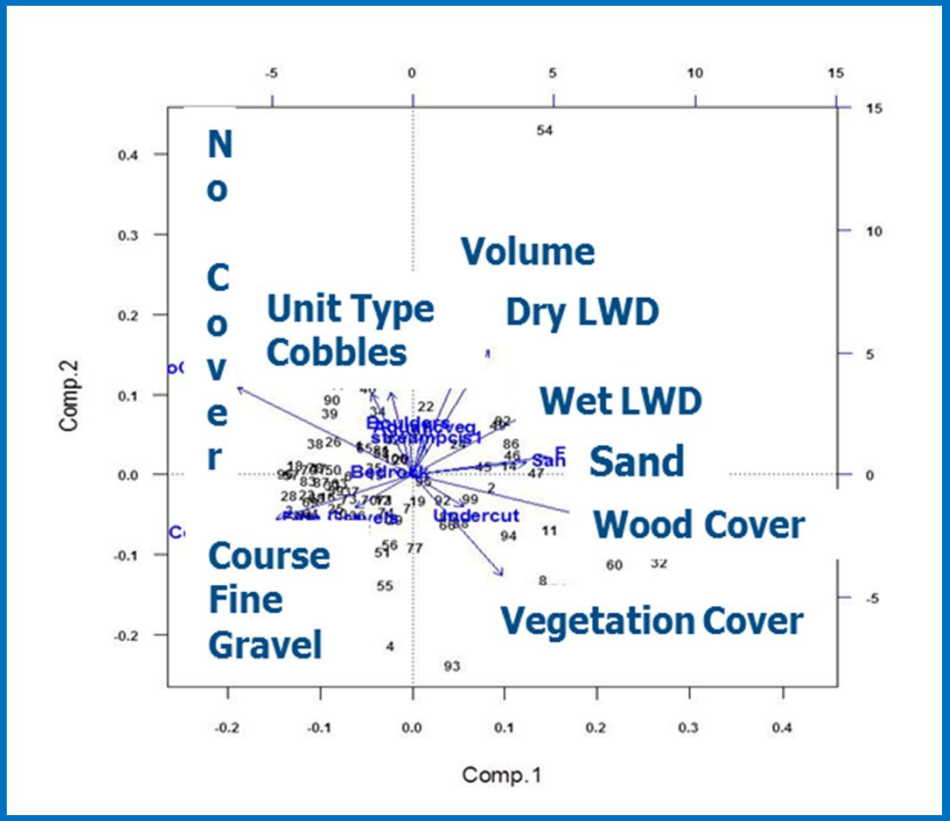
Reduced data set of variables used in factor analysis to evaluate relationships between salmonid abundance and physical stream habitat.

Unit Abundance*	Stream	Unit Type	Percent Bedrock	Boulders	Cobbles
Coarse Gravels	Fine Gravels	Sand	Fines	Woody Debris Cover	Live Overhead Cover
Undercut Banks	No Cover	Aquatic Vegetation Cover	Unit Volume	Dry LWD Abundance	Wet LWD Abunance

* Dependent variable: coho salmon, steelhead YoY, Steelhead Y+, or Steelhead Y++.


z_a
ε_a
F_2
Unit Circle
ℓ_{a2}
$\hat{z}_a$
ℓ_{a1}
F_1


Scree Plot
Number of factors for analysis: 7
Variances
3.0
2.5
2.0
1.5
1.0
Choose all factors which have variances > 1
Comp.1
Comp.3
Comp.5
Comp.7
Comp.9


No Cover
Volume
Unit Type
Cobbles
Dry LWD
Wet LWD
Sand
Wood Cover
Course
Fine
Gravel
Vegetation Cover
Undercut
Comp.2
Comp.1

Factor Analysis:

Factor names, factor loadings (variables), and loading coefficients. Bold indicates significant coefficients.

Variable	Factor Names						
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	**Factor 7**
Bedrock							
Boulders				**0.59**			
Cobbles				**0.89**			
Coarse Gravels					-0.38	**-0.74**	
Fine Gravels						**-0.46**	
Sand					**0.96**		
Fines						**0.64**	
Large Wood Wet		**0.75**					
Large Wood Dry	0.31	**0.47**		0.34			
Overhead Vegetation Cover			**0.76**				
Overhead Wood Cover		**0.72**					
Aquatic Vegetation Cover							
Undercut Banks							**0.98**
No Cover		**-0.43**	**-0.86**				
Unit Type							
Unit Volume	**0.79**				0.32		
Stream				**0.33**			

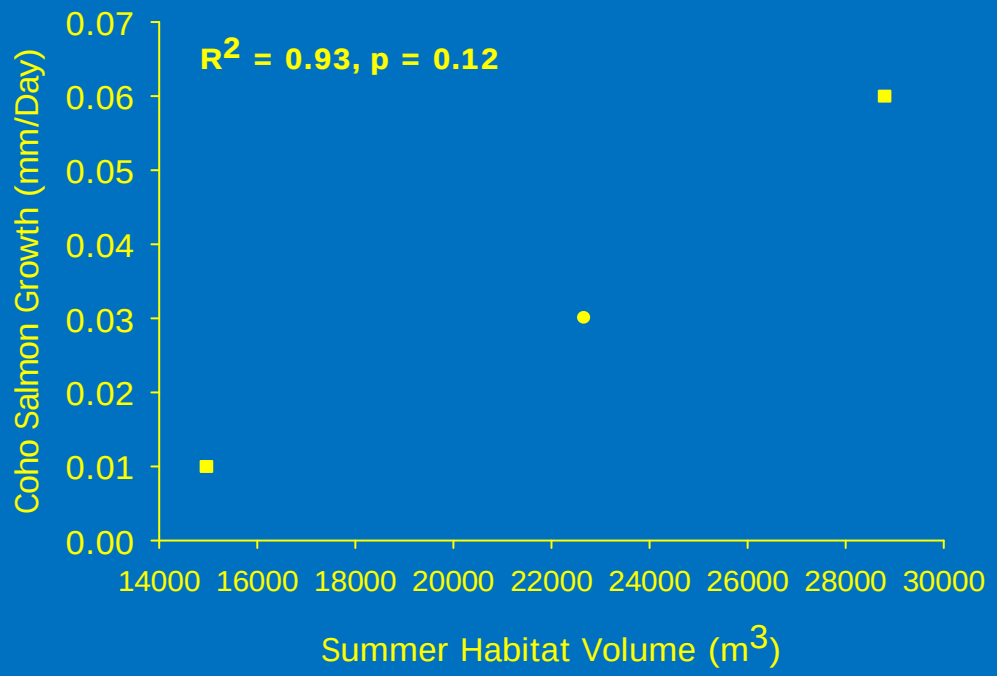
Negative Binomial Regression Modeling

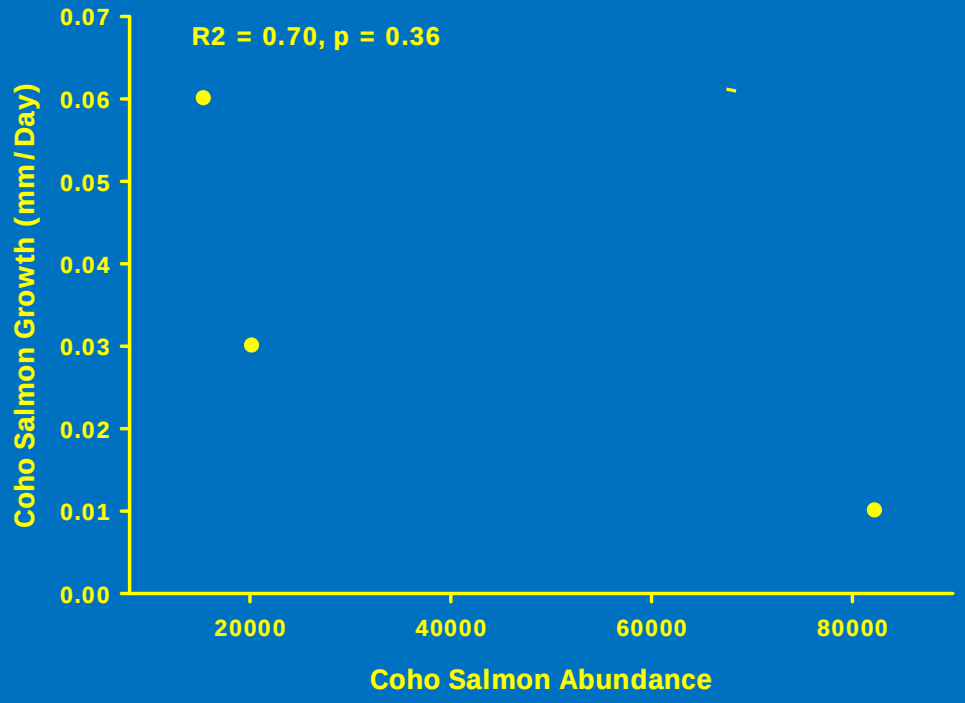
Habitat factors associated with salmonid abundance

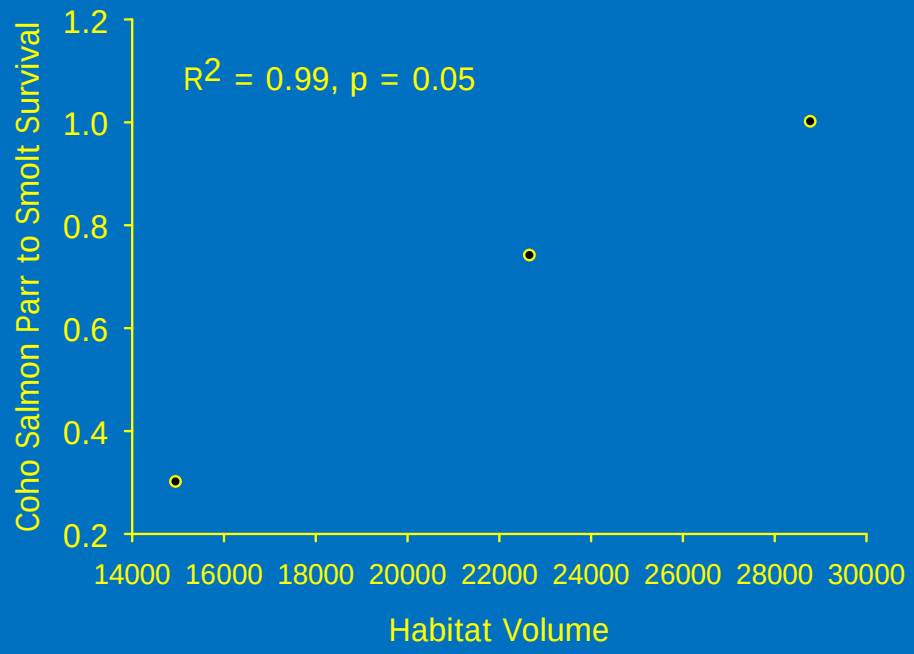
Salmonid Abundance	Factor Names						
	Volume and Dry Large Wood	Wood	Overhead Vegetation	Turbulent Water Stream And Dry Large Wood	Slow Water Volume	Fast Water	Undercut Banks
Coho Salmon	**Positive**	NS	NS	NS	**Positive**	**Negative**	NS
Steelhead YoY	**Positive**	NS	**Negative**	**Negative**	NS	**Negative**	NS
Steelhead Y+	**Positive**	**Positive**	**Negative**	**Negative**	**Positive**	**Negative**	**Positive**
Steelhead Y++	**Positive**	**Positive**	NS	NS	NS	NS	NS

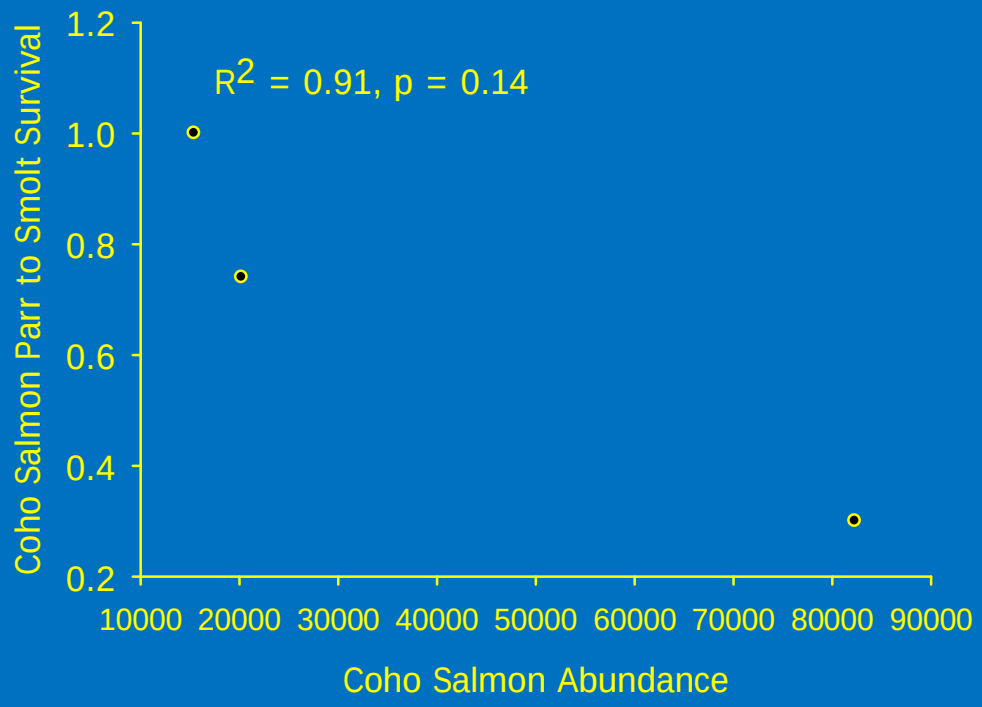
Coho Salmon Abundance and Habitat Variables

Variable	Factor Names						
	Volume and Dry Large Wood	Wood	Overhead Vegetation	Turbulent Water Stream And Dry Large Wood	Slow Water Volume	Fast Water	Undercut Banks
Bedrock							
Boulders				**0.59**			
Cobbles				**0.89**			
Coarse Gravels					-0.38	**-0.74**	
Fine Gravels						**-0.46**	
[redacted]					**0.96**		
Fines						**0.64**	
Large Wood Wet		**0.75**					
Large Wood Dry	0.31	**0.47**		0.34			
Overhead Vegetation Cover			**0.76**				
Overhead Wood Cover		**0.72**					
Aquatic Vegetation Cover							
Undercut Banks							**0.98**
No Cover		**-0.43**	**-0.86**				
Unit Type							
[redacted]	**0.79**				0.32		
Stream				**0.33**			

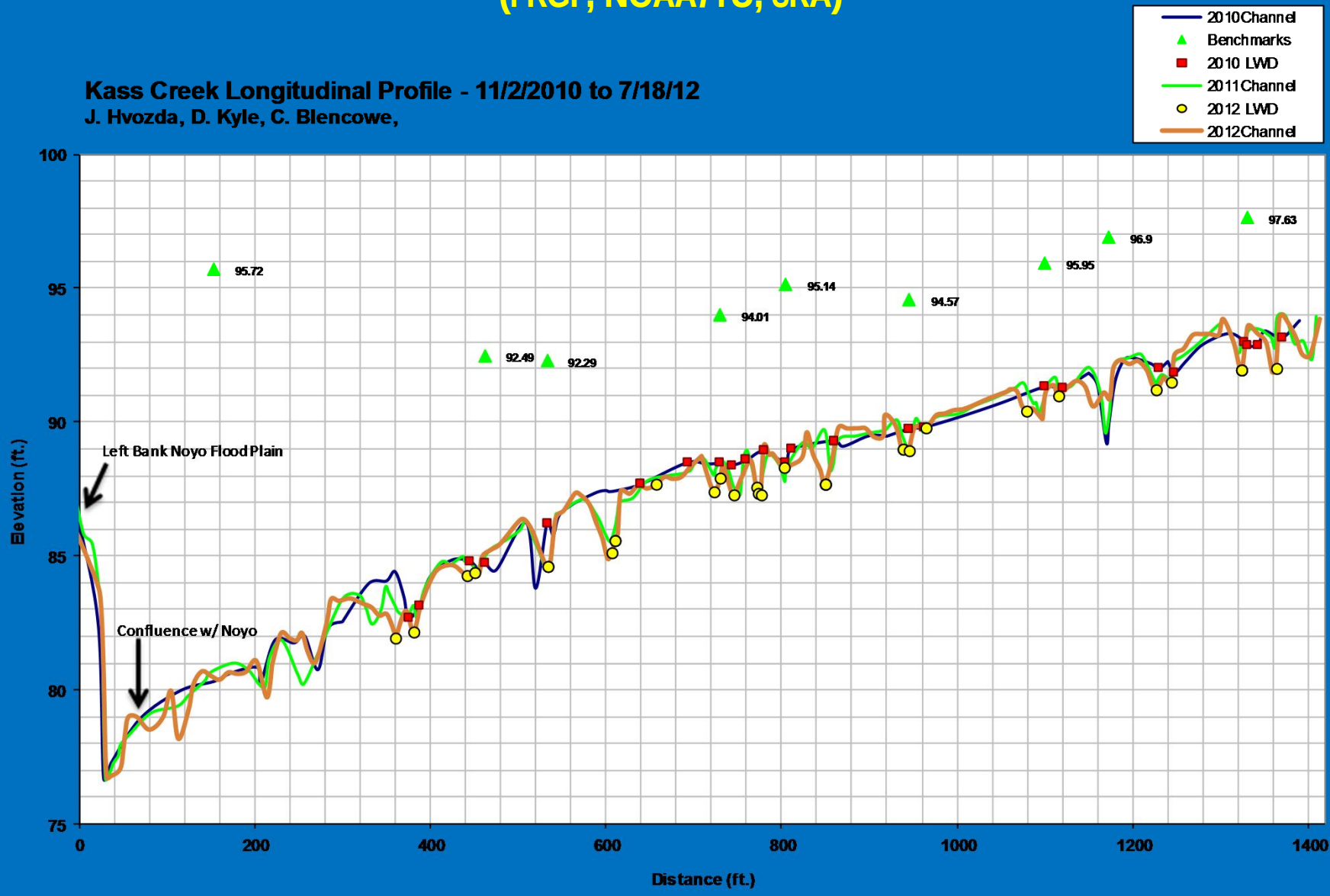

R^2 = 0.93, p = 0.12
Coho Salmon Growth (mm/Day)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
14000 16000 18000 20000 22000 24000 26000 28000 30000
Summer Habitat Volume (m^3)


R2 = 0.70, p = 0.36
Coho Salmon Growth (mm/Day)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
20000
40000
60000
80000
Coho Salmon Abundance


Coho Salmon Parr to Smolt Survival
1.2
1.0
0.8
0.6
0.4
0.2
R2 = 0.99, p = 0.05
14000 16000 18000 20000 22000 24000 26000 28000 30000
Habitat Volume


Coho Salmon Parr to Smolt Survival
1.2
1.0
0.8
0.6
0.4
0.2
R2 = 0.91, p = 0.14
10000 20000 30000 40000 50000 60000 70000 80000 90000
Coho Salmon Abundance

Longitudinal Profile of Lower 1400' Project Reach in Kass Creek (Noyo River) (2010-2012) (FRGP, NOAA/TU, SRA)



Adding roughness elements to streams in the Redwood Region may help reconnect these channels to floodplains, an important factor in over-winter survival for juvenile coho and steelhead

Acknowledgements

Chris Bell, JJ Brunner, Mike Zontos, Chris Jordan, Wendy Holloway, Dave Wright, Emily Lang, Andy MCClarry, Greg McClarry, Elizabeth MacKey, Katlyn Jordan, Chris Chavez, Stan Allen, Joe Ferreira, and FRGP